Evidence of long-range transport of Mexico City outflow based on CMET balloon trajectories during the MILAGRO 2006 campaign

Preliminary author list (additions expected)

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Abstract

During the MILAGRO 2006 campaign, free-floating Controlled Meteorological (CMET) balloons made observations relevant to long range transport, mixing, and dispersion during intensive study periods. The balloons, which were launched from within the Mexico City Metropolitan Area (MCMA), made repeated profile measurements of temperature, relative humidity, and winds as they drifted with the mean flow over distances of up to 1100 kilometers. On March 11-12, a pair of CMET balloons launched into the polluted residual layer in the northeast quadrant of the MCMA followed highly divergent paths with one balloon exiting the basin to the east and later returning and the other exiting through the south gap. On March 18-19, another pair of balloons was launched from the northwest quadrant of the MCMA just after the DOE G-1 aircraft had finished sampling in the area. The balloons were intercepted again after 28 hours by the NCAR C-130 near the US border. A preliminary analysis of the balloon profiles and the aircraft intercept data are presented. The data are the first to combine repeating in-situ meteorological balloon soundings with initial and final aircraft intercepts in a long-range transport event. We expect these data to be of significant value in constraining and evaluating meteorological and gas-aerosol

Figure 1. Four CMET balloons ready for launch at the Aircraft Operations Center in Veracruz. Each balloon contains an inner high-pressure balloon that acts as a lightweight helium tank; the altitude of the balloons can be regulated during flight by pumping helium into and out of the inner balloon. At the base of the balloons is a small payload consisting of a satellite modem, microcontroller, gps receiver, aspirated temperature and humidity sensors, and a battery pack.

Figure 2. Two CMET balloons being loaded into a minivan for transport to Mexico City. The use of many different launch sites allowed great flexibility in targeting pollution events; flight plans could be adjusted in real time using the latest available data from MILAGRO aircraft, surface stations, and satellites. Once at the launch site, the balloon could be released within minutes.

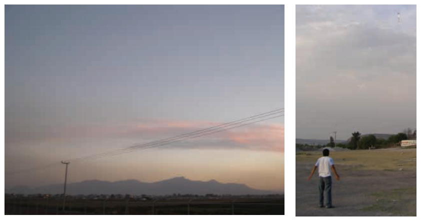

Figure 3. High levels of pollution are still visible (left photo) in the northwest quadrant of Mexico City approximately one hour after two CMET balloons were launched to track the event. Student Oscar Martinez watches (right photo) as the last balloon disappears into the haze.

March 11-12 CMET Flights

Flow through the South Gap

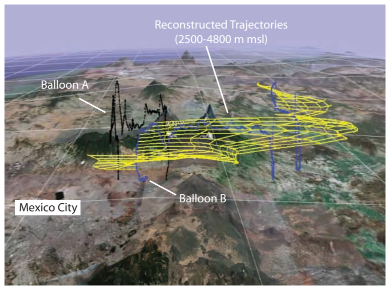

Figure 4. On March 11, an attempt to launch two CMET balloons into a northeast transport event turned into an unexpected gap flow experiment. The first balloon to be launched (shown in black) turned 180 degrees, re-entered the basin and was terminated. The second balloon (shown in blue) headed south and rapidly exited the gap while performing soundings. Trajectories reconstructed from these soundings show air exiting the basin aloft and cooler, wetter air entering the city at the valley floor.

March 11-12 and 18-19 Flights

Flexpart/MM5 Simulations

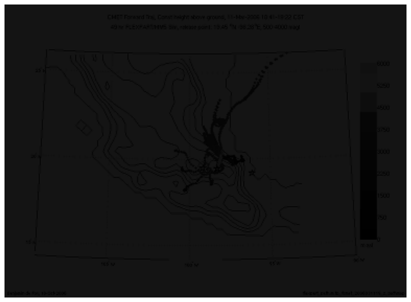

Figure 5. Flexpart/MM5 model trajectories for the gap flow event on March 11. While the model does not show the pronounced outflow to the south aloft and inflow at the surface, it does show signs of complex circulation. It is notable that this particular model run began tens of kilometers to the east of the balloon launch site, one possible reason for the discrepancy.

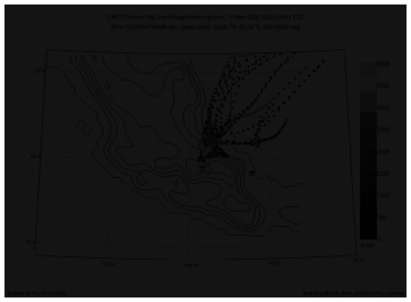

Figure 6. Simulation of trajectories leaving the Mexico City basin on March 18 at the time and location of the paired balloon launch. Model predictions compared favorably with the balloon trajectories, especially considering that the model was run at constant height above ground level while the balloons were fixed relative to sea level. The trajectories reconstructed from the balloon data (see Fig. 7) have a greater northward component and possibly show more shear and faster transport.

March 18-19 CMET Flights

Direct Observation of Long-Range Transport

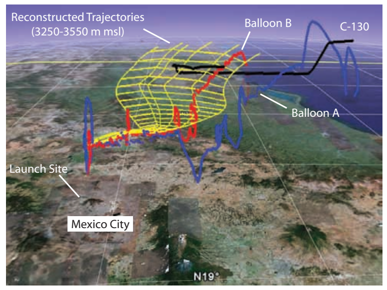

Figure 7. On March 18-19, two balloons launched into a polluted airmass in the northwest quadrant of Mexico City travelled approximately 800 km to the edge of U.S. airspace. The balloons performed repeated soundings during transit, measuring atmospheric stability, humidity, and wind shear. Trajectories are reconstructed from the wind profiles at 50 m altitude intervals. The reconstructed trajectories from the two independent balloons lie within the same space and have approximately the same shear, so only one is shown (in yellow corresponding to the red balloon). This excellent agreement provides a high level of certainty for the C-130 intercept (in

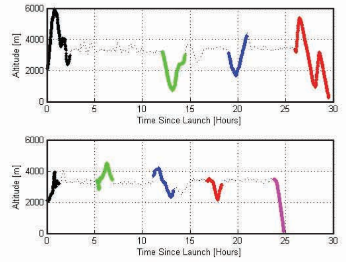

Figure 8. Altitude profiles of the two balloons on March 18-19.

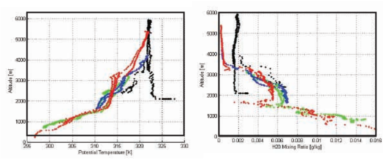

Figure 9. Evolving profiles of potential temperature and water vapor concentration. Note the wet layer over the coastal plain.

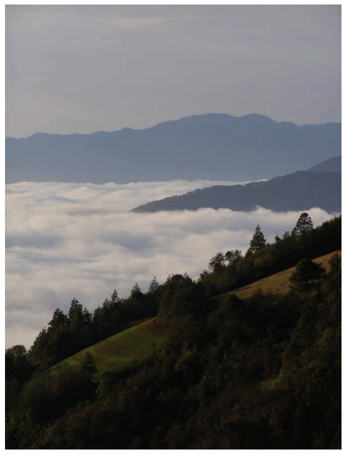

Figure 10. Above the Veracruz plain, pollution is being advected off the plateau and over the stable marine layer much like the event of March 18-19 further north.

March 18-19 CMET Flights

NCAR C-130 and DOE G-1 Intercepts

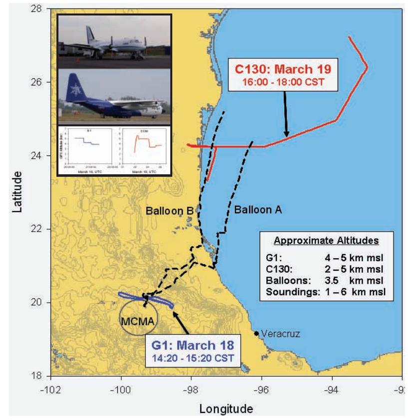

Figure 11. Map showing the two balloon trajectories and the aircraft flight paths on March 18-19.

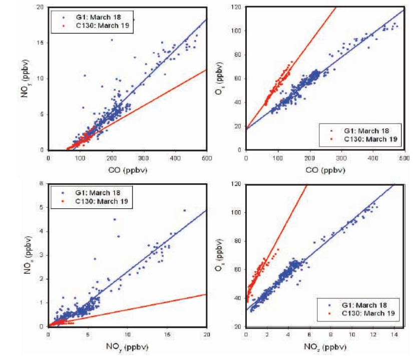

Figure 12. Trace gas concentrations measured by the G-1 and C-130 are consistent with a quasi-Lagrangian experiment in an aged and diluted airmass. The dilution is not surprising given the strong wind shear observed during transport (Fig. 7).

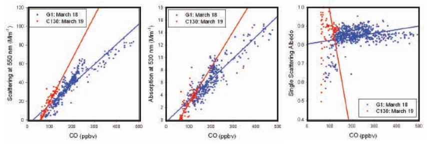

Figure 13. Scattering and absorption both increase with time as particles likely grow, but scattering appears to dominate.

Conclusions

Altitude-controlled balloons performing repeated soundings can measure trajectories, wind shear, atmospheric stability, and chemical concentrations within an advecting slab of the atmosphere. These enhanced trajectories can significantly increase confidence in time-series measurements of atmospheric processes.

Data from a coordinated G-1, C-130, and balloon flight on March 18-19 suggests that O_3 concentrations increased with time even as dilution reduced NOy substantially. Observed aerosol scattering and absorption relative to CO are also found to increase in the aged air mass compared to near field measurements.

Acknowledgements

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